

Chapter 4

A Trajectory Ontology Design Pattern for Semantic Trajectory Data Warehouses: Behavior Analysis and Animal Tracking Case Studies

Marwa Manaa

University of Tunis, Tunisia

Thouraya Sakouhi

University of Tunis, Tunisia

Jalel Akaichi

University of Bisha, Saudi Arabia

ABSTRACT

Mobility data became an important paradigm for computing performed in various areas. Mobility data is considered as a core revealing the trace of mobile objects displacements. While each area presents a different optic of trajectory, they aim to support mobility data with domain knowledge. Semantic annotations may offer a common model for trajectories. Ontology design patterns seem to be promising solutions to define such trajectory related pattern. They appear more suitable for the annotation of multiperspective data than the only use of ontologies. The trajectory ontology design pattern will be used as a semantic layer for trajectory data warehouses for the sake of analyzing instantaneous behaviors conducted by mobile entities. In this chapter, the authors propose a semantic approach for the semantic modeling of trajectory and trajectory data warehouses based on a trajectory ontology design pattern. They validate the proposal through real case studies dealing with behavior analysis and animal tracking case studies.

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INTRODUCTION

Advances in pervasive systems triggered by the incredible technical evolution of mobile devices and positioning technologies led to the eruption of disparate, dynamic, and geographically distributed mobility data. For a long while, location sensing devices and wireless networks started becoming widely untethered (Yan & Chakraborty., 2007). As a result, disparate mobility data revealing the details of instantaneous activities conducted by mobile entities can be collected and used for any mobile object trajectory reconstruction.

Note that, trajectory data, which is a record set of gathered mobility data, can be associated to different domain-specific information. Trajectories are naturally represented as *raw trajectory* denoting a sequence of temporally-indexed positions. For example, pedestrian displacement is described using a time-varying point which is a point whose position evolves over the time. In other cases, such as studying bird migration displacement, trajectories are defined by decision spatio-temporal points i.e., stops and moves according to predefined paths i.e., sub-trajectories. We will refer to the latter cases as *structured trajectory* (Spaccapietra et al., 2008). In other cases, *trajectory with Region Of Interest (ROI)* (Giannotti et al., 2007) represents trajectory data as a sequence of regions and time intervals. The phenomenon of adopting raw trajectory referencing domain ontologies by organizations generates a new type of trajectory, called *semantic trajectory*. *Semantic trajectory* (Alvares et al., 2007), (Bogorny et al., 2009), (Yan & Chakraborty., 2007), (Richter et al., 2015) and *trajectory with Semantic ROI* (Yan., 2009) annotates decision points with con-textual information and enrich them by links with geographic and application domain concepts. In other cases, *space-time path* (Wannous et al., 2013) extends semantic trajectories with mobile object activity performed during the travel. An example of such trajectories occurs in Location-Based Social Networks (LBSN), where the raw trajectory are user check-ins to Points Of Interest (POI) and the contextual information includes names of POI and activities during the travel.

In a highly heterogeneous and dynamic environment, such as the Web, arriving at commonly agreed and stable domain ontologies is a prone-to-fail task and progress has been slow over the last years (Hu et al., 2013). Ontology design patterns have emerged as more flexible, reusable and manageable modeling solutions (Gangemi., 2005). It may provide common model for different representations of trajectory data where designers can pick the appropriate knowledge to define trajectories in view of share, exchange or integration. Alongside, data warehousing techniques are expected to analyze and extract valuable information from heterogeneous trajectory data sources.

In previous papers (Manaa & Akaichi., 2016) and (Manaa & Akaichi., 2017) authors presented respectively a trajectory ontology and a semantic approach for modelling trajectory data warehouses. In this paper we extend aforementioned papers and we set up (i) a Trajectory Ontology Design Pattern (TrODP) for Trajectory Data Warehouses (TrDW). We emphasize the geometric module in order to represent common structures encountered in trajectories associated with links to application and geographic modules in order to maintain semantic interoperability. More than that, the TrODP provides genericity as it covers most important trajectory data works and ensures consensuality because it is a deal on a consensual knowledge by a community. Furthermore, (ii) the TrODP serves to define the TrDW conceptual model. Our proposal permits to save too much designers efforts and time needed to acquire domain knowledge since the latter is extracted from the TrODP. The Semantic Trajectory Data Warehouse (STrDW) will mainly highlight the trajectory to be seen as a first class semantic concept, providing an ontology-based multidimensional model.

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